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(54) Title: <b>OPTIC DEVICES FORMED FROM MELT PROCESSABLE THERMOPLASTIC MATERIALS HAVING A HIGH REFRACTIVE INDEX</b>			
(57) Abstract <p>This invention relates generally to optic devices such as lenses, (monofocal and multifocal), progressive lenses, lens blanks, and lens preforms having a specific formula.</p> <p>Michael Martin 540-951-9376 Virg Tech Inv. Prof.</p>			

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Optic Devices Formed From Melt Processable Thermoplastic Materials Having a High Refractive Index

Field of the Invention

This invention relates generally to optic devices such as lenses, (monofocal and multifocal), progressive lenses, lens blanks, and lens preforms.

Background of the Invention

Lenses formed from thermoplastic material have enjoyed increasing popularity. Advances in the production of such lenses have included the use of materials that are lighter and free of unwanted color.

An attractive and important way to optimize a plastic lens is by use of materials having a high index of refraction. This enables lens designers to design thinner lenses having surfaces with larger radii of curvature.

Aromatic thermoplastics have been recognized as potential candidates for the fabrication of high refractive index materials for optical applications, particularly in the area of spectacle wear. Aromatic polycarbonates typify this approach to optical applications, and have an index of refraction of about 1.59. These materials are however known to be subject to undesirable chromatic aberration.

Aromatic polyethers that contain the triphenyl phosphine oxide moiety in the repeat unit have been described in the literature. Aromatic polyethers containing the phosphine oxide group are shown or suggested and described in U.S. Patent Nos. 4,108,857 and 4,175,175. Some work has been attempted on the use of these materials as short range optical fibers, and as plasma-resistant coatings.

These materials may be synthesized by the reaction of a variety of bisphenols with 4,4'-bis(fluorophenyl) phenyl phosphine oxide (BFPPO) in the presence of a base such as potassium carbonate in dipolar aprotic solvents such as N-methyl pyrrolidinone (NMP) or N,N-dimethyl acetamide (DMAC). Techniques for the synthesis of these compounds are known and many of their physical properties are well documented in the literature. See, for example, C.D., Smith, et al, SAMPE Symps Exib. Vol. 35, No. 1, pp 108-22 (1990); R.L. Holzberlein, et al, Polymer Prepr., Vol. 30, No. 1 p. 293 (1989); D.B. Priddy, et al, Polymer Prepr., Vol. 34, No. 1, pp. 310-11 (1993); D.B. Priddy et al, Polymer Prepr. Vol. 33, No. 2, pp.231-32 (1992); C.D. Smith, et al., Polymer Prepr., Vol. 32, No. 1, pp. 93-5 (1991); C.D. Smith, et al, High Perform. Polymers, Vol. 3, No. 4, pp. 211-29 (1991). Controlled molecular weight with non-reactive end-groups may be generated, for example, by employing a monofunctional monomer such as 4,tert-butyl phenol.

### Summary of the Invention

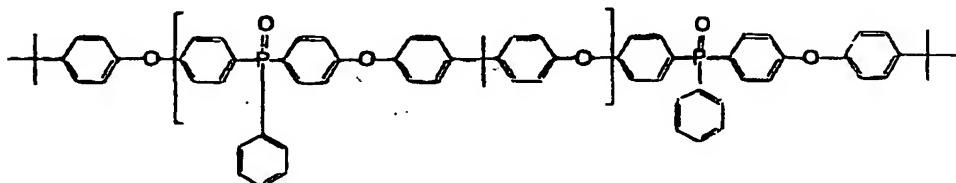
The present invention relates to optic devices formed from phosphine oxide containing aromatic polyethers and copolymers with non-reactive end-groups. These controlled molecular weight polyethers demonstrate good mechanical properties as well as favorable optical properties such as a refractive index of at least 1.63, good clarity, and light color. These are critical to the development of good quality, thin and lightweight ophthalmic lenses. Optic devices made from these materials are also less subject to chromatic aberrations.

Non-reactive chain ends are believed to help maintain stable melt viscosity during the processing operation, and to ensure that there is no change in melt viscosity due to chain extension or branching during processing, which also leads to loss of optical properties. The superior thermo-mechanical stability of these materials permit them to be processed at fairly high temperatures without thermal and mechanical degradation.

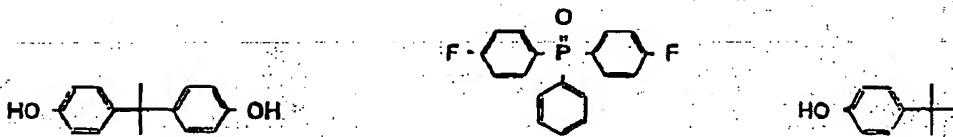
### Detailed Description of the Invention

The aromatic polyethers that contain the phosphine oxide moiety in the backbone of the polymer chain possess the critical properties for their successful application in the area of ophthalmic lenses for spectacle eye-wear. The presence of the phosphine oxide moiety in the backbone of the polymer chain contributes to higher refractive index as well as improved thermal and mechanical properties. These materials demonstrate high glass transition temperatures in the range 200 - 225°C and therefore have to be processed at elevated temperatures such as 325 - 350°C. The mechanical properties of these materials indicate that they are tough, ductile and yet glassy materials under ambient conditions and therefore facilitate the generation of thin lenses that possess good impact resistance.

A properly end capped, non-reactive phosphine oxide containing aromatic polyether is described as Formula I below:

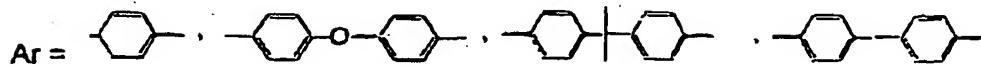
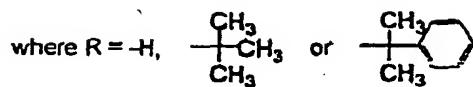
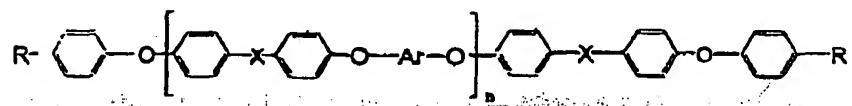


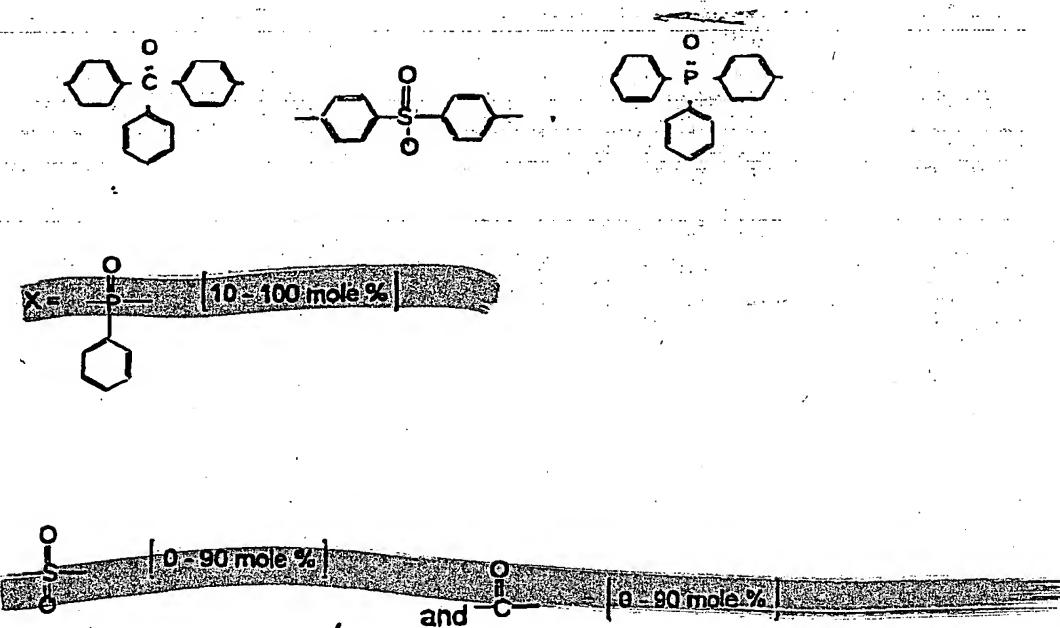
The polymer may be formed by reacting BFPO, bisphenol A and a 4.-tert butyl phenol, shown below, under the conditions described Example 1.



Other homopolymers may be generated by employing a variety of bisphenols instead of Bisphenol 'A' such as hydroquinone, biphenol, 4,4'-oxy diphenol or bis(4-hydroxy phenyl) sulfone.

~~A number of polyether copolymers may be envisaged by substituting part of the phosphine oxide monomer with either 4,4'-dichloro diphenyl sulfone or 4,4'-difluoro benzophenone. The general structure of such copolymers may be shown as follows:~~





However, anhydrous morphologies must be maintained.

Optic devices fabricated from these materials are optically clear, and thinner at their edges than conventional ophthalmic plastic lenses owing to their higher refractive index values.

#### Example 1 (Preparation of Polymer)

31.43 grams, (0.1 moles) of 4,4'-bis(fluorophenyl)-phenyl phosphine oxide (BFPO) [Mol. Wt. = 314.2706] along with 22.25 grams (0.098 moles) of bisphenol 'A' [Mol. Wt. = 228.2902] along with 0.70 (0.005 moles) of 4-*tert.* butyl phenol [Mol. Wt. = 138.209] were charged into the 4-necked reaction flask fitted with a bubble tube for argon, an overhead mechanical stirrer and a Dean-Stark trap connected to a reflux condenser. The reactants were dissolved in enough DMAc to make up a 30% solution by weight in a mixture of DMAc and chlorobenzene (80:20). The chlorobenzene served to function as an azeotroping solvent to efficiently remove the water of the condensation reaction as it was formed during the polymerization. The reaction was initially held at 135 - 140° for 4 hours till the water of condensation was completely distilled off. Subsequently, the reaction temperature was gradually raised to about 165°C and held there for an additional 16 hours. The reaction product was then allowed to cool down to room temperature and filtered to remove the inorganic salts and neutralized with glacial acetic acid and isolated by precipitation into rapidly agitated methanol/water mixture in a high speed blender. The precipitate polymer was then filtered and dried in a vacuum oven at about 200°C overnight after being washed repeatedly with methanol to remove all traces of solvent.

The preferred range of number average molecular weight for these polymers is approximately 15,000 - 25,000 g/mol. At above a number average molecular weight of 25,000 g/mol., the melt viscosity may be too high for rapid processing. Polymers have therefore been synthesized with a targeted molecular weight of 20,000 g/mol. It is known from the literature that the polymer chain length, and thus the molecular weight, of the polymer can be adjusted by controlling the ratio of phosphine oxide to aryl moieties used in the synthesis process.

#### Example 2 (Formation of Lens)

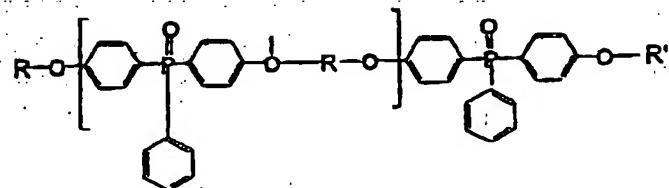
A single vision lens of diameter 80 mm, with a refractive index of 1.66, a spherical power of -6.00 D at a center thickness of 1.0 mm is made of the polymer of Example 1 by processing the polymer melt through an extruder and then forming a lens from the heated extrudate in a conventional injection molding apparatus. The edge thickness for such a lens is 8.8 mm.

A corresponding high index lens made of polycarbonate having a refractive index of 1.58 under the same set of parameters (i.e. center thickness of 1.0 mm, spherical power of -6.00 D, and lens diameter 80mm.) would have an edge thickness of 10.0mm..

The foregoing non-limiting example is provided as an illustration. The scope of the present invention is defined only by the following claims.

We claim.

1. An optic device formed from the following polymeric material:

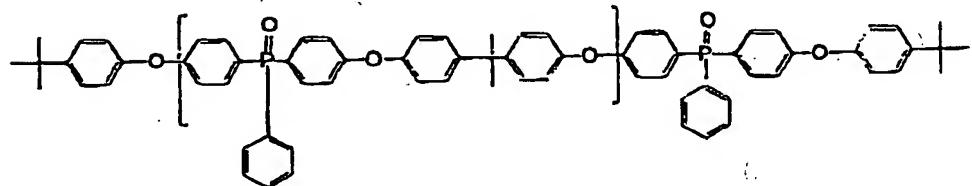


where R and R' are substituted or unsubstituted aryl groups.

2. The optic device of claim 1, wherein the molecular weight of the polymer is from about 15,000 to about 25,000.

3. The optic device of claim 1 wherein the molecular weight of the polymer is about 20,000.

4. The optic device formed from the following polymeric material:

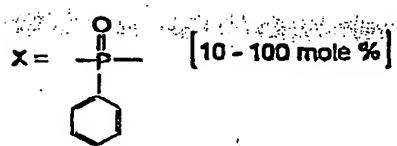
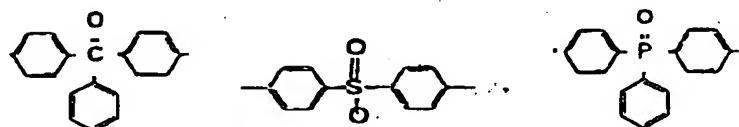
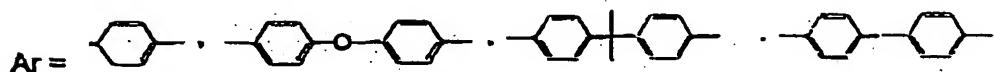
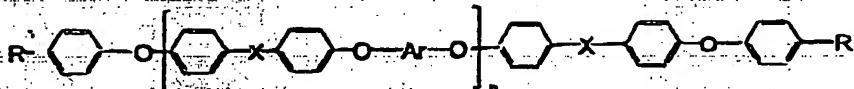


5. The optic device of claims 1 through 4, wherein the optic device is a spectacle lens.

6. The optic device of claims 1 through 4, wherein the optic device is a lens blank.

7. The optic device of claims 1 through 4, wherein the optic device is a lens preform.
8. The optic device of claims 1 through 4, wherein the optic device is a progressive lens.
9. The optic device of claims 1 through 4, wherein the optic device is a bifocal lens.
10. An optic device formed from a polymeric material formed by the polymerization of (a) a phosphine oxide moiety, and (b) a cyclic aryl moiety, a bicyclic aryl moiety, or mixtures thereof.
11. An optic device according to claim 11 wherein the aryl moiety is a mixture of bisphenol and butyl phenol.
12. The optic device according to claim 11 or 12, wherein the optic device is a spectacle lens.
13. The optic device according to claim 11 or 12, wherein the optic device is a lens blank.
14. The optic device according to claim 11 or 12, wherein the optic device is a lens preform.
15. The optic device according to claim 11 or 12, wherein the optic device is a progressive lens.
16. The optic device according to claim 11 or 12 wherein the optic device is a bifocal lens.

17. An optic device formed from the following polymeric material:



# INTERNATIONAL SEARCH REPORT

International application No:  
PCT/US98/14989

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(9) :C08F 4/00; G02C 7/02

US CL : 525/255, 191, 196, 200, 212; 351/177

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 525/255, 191, 196, 200, 212; 351/177

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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CAS

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Please See Continuation of Second Sheet.	

Further documents are listed in the continuation of Box C.  See patent family annex.

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Date of the actual completion of the international search

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**INTERNATIONAL SEARCH REPORT**

International application No.  
PCT/US98/14989

**C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT**

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Chem. abstr., Vol. 115, No. 21, 25 November 1991 (Columbus, OH, USA), page 86, column 1, the abstract No. 234048s, WANG, B., "High refractive index hybrid ceramer materials prepared from titanium tetraisopropoxide and poly(arylene ether phosphine oxide) through sol-gel processing", Polym. Commun. 1991, 32(13), 400-2 (Eng.)	1-18
Y	Chem. abstr., Vol. 128, No. 12, 23 March 1998 (Columbus, OH, USA), page 614, column 1, the abstract No. 141137y, DING, YONG, "Cyclic(arylene ether) oligomers containing the phenylphosphine oxide moiety", Polym. Chem. 1998, 36(4), 519-526 (Eng.).	1-18
Y	Chem. abstr., Vol. 127, No. 22, 01 December 1997 (Columbus, OH, USA), page 598, column 2, the abstract No. 307748e, RILEY, D.J., "Synthesis and characterization of flame resistant poly(arylene ether)s", Polym. Eng. Sci. 1997, 37(9), 1501-1511 (Eng.).	1-18
Y	Chem. abstr., Vol. 120, No. 25, 20 June 1994 (Columbus, OH, USA), page 11, column 2, the abstract No. 324365a, HILL, DAVID J.T., "The radiation chemistry of poly(arylene ether phosphine oxides)", Polym. Prepr. (Am. Chem. Soc., Div. Polym. Chem.), 1993, 34(2), 195-6 (Eng.).	1-18
Y	Chem. abstr., Vol. 118, No. 11, 15 March 1993 (Columbus OH, USA), page 65, column 1, the abstract No. 103350y, SMITH, C.D., "Unique characteristics derived from poly(arylene ether phosphine oxides). High Perform. Polym. 1991, 3(4), 211-29 (Eng.)	1-18
Y	Chem. abstr., Vol. 114, No. 25, 24 June 1991 (Columbus, OH, USA), page 6, column 2, the abstract No. 247887u, SMITH, C.D., "Poly(arylene ether) phosphine oxide thermoplastic materials for potential electronic applications", Int SAMPE Electron. Conf. 1989, 3 (Electron. Mater. Processes), 141-7 (Eng.).	1-18
Y	Chem. abstr., Vol. 114, No. 9, 04 March 1991 (Columbus, OH, USA), page 7, column 2, the abstract No. 82663c, SMITH, C.D., "Synthesis and characterization of poly(arylene ether phosphine oxides)", Int SAMPE Symp. Exhib. 1990, 35 (1, Adv. Mater.: Challenge Next Decade), 108-22 (Eng.).	1-18